F. 4

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE AND MISSILE SYSTEMS CENTER (AFMC)
LOS ANGELES, CA

1.

SMC/CI
2420 Vela Way, Ste 1467-D9
Los Angeles AFB, CA 90245-4659

National Aeronautics and Space Administration, Headquarters
Washington, DC 20546-0001

Dear Mr. Tilford,

Enclosed is the Defense Meteorological Satellite Program (DMSP) data you requested for incorporation into your Mission to Planet Earth Reference Handbook. We understand S M Systems and Research Corporation (SMSRC) which operates NASA's Earth Science and Support office will be compiling the data handbook for you. Per your request we are sending a copy of this data on disk directly to SMSRC, Mr. David Dokken.

DMSP is pleased to support this effort which will help immensely toward making our current and planned sensor data more accessible to the US and international scientific communities. We offer our continued assistance as you finalize writing of this handbook. If you have any questions regarding our inputs, please contact Major Maritza Crabtree at 310-336-4 146.

Sincerely,

John A. Goyette, Colonel, USAF
System Program Director
Defense Meteorological Satellite Program

Enclosure:
DMSP Data Sheets (34 pages), 11 March 94

CONTRACTOR
LIBRARY

Defense Meteorological Satellite Program

MISSION:

Platform Type: LEO
Sponsoring Agency: Department of Defense and US Air Force
Spacecraft Contractor: Martin-Marietta Corporation
Primary Mission Objectives: The DMSP series has served as the primary Department of Defense (DoD) operational meteorological satellite system since the 1970's. Comparable to the NOAA POES and GOES series, DMSP utilizes a serial numbering system to differentiate satellites on orbit and those in ground storage or under development (F- for the former and S- for the latter). These satellites collect and disseminate visible and infrared cloud data and other meteorological, oceanographic, and solar-geophysical measurements. The stored data is relayed to the Air Force Global Weather Central and Fleet Numerical, Meteorological, and Oceanographic Center over domestic communication satellites from four Readout Sites (Fairchild Satellite Operations Center, Fairchild AFB, WA; Thule Tracking Station, Greenland; New Hampshire Tracking Station, New Boston, NH; and Hawaii Tracking Station, Kaena Point, HI). This data is used both operationally and for environmental analysis in the DoD and civilian research communities. Some of the data is relayed via the Shared Processing Network to the National Environmental Satellite, Data and Information Service (NESDIS) where it is processed for the US and European Weather Agencies. Real-time data is transmitted to tactical terminals around the world. Two real time services are available: high resolution imagery at 1.024 Mbits/second and a lower resolution smooth data set at 66 kbits/second (effective data rate). All links are currently encrypted. The discussion below covers DMSP-F8 through -S20.

Primatv Measurements/Products: Day and Night Global cloud cover, cloud typing and height, snow and ice cover, surface albedo are measured with the Operational Linescan System (OLS).

Secondary Mission/Objectives: Microwave sensors aboard the DMSP satellites obtain vertical temperature profiles from both the upper and lower atmosphere, water vapor profiles, surface moisture, sea ice. and ocean surface wind speed. Other sensors provide in-situ data on the ionosphere at 833 kilometers, measuring electron and ion densities and temperatures, currents. and precipitating particles. Later flights will add the capability to remotely sense the electron and ion densities between 120 and 350 kilometers using ultraviolet airglow oi the E and F regions.

DMSP digitally formatted data is available at National Geophysical Data Center in Boulder, Colorado. The digital data is available with observations starting March 9, 1992, with OLS imagery on film available from 1972-1990. Since Jan 1, 1991, only samples of OLS imagery are available on film. Processed seven channel passive microwave radiometer (SSM/I) data since August 1987 is also available from National Snow and Ice Data Center on CD ROM.

The data derived from the SSM/I have been selected to be part of the EOS Data and Information System (EOSDIS). The SSM/I Pathfinder effort begins with the processing of Benchmark Period data from the DMSP-F8 satellite and covers the time frame from August 1987 to November 1988.

Phillips Laboratory has archived the DMSP ionospheric sensors from 1973 to 1993 when the function was replaced by the National Geophysical Data Center.

Instruments:

Operational Linescan System (OLS)
Special Sensor Gamma Ray Detector (SSB/X-2)
Special Sensor Ionospheric Plasma Drift/Scintillation Monitor (SSIES-2, SSIES3)
Special Sensor Magnetometer (SSM)
Special Sensor Precipitating Electron/Ion Spectrometer (SSJ/4,SSJ5)
Special Sensor Microwave/Imager (SSM/I)
Special Sensor Microwave Imager/Sounder (SSMIS)
Special Sensor Microwave Temperature Sounder (SSM/T-1)
Special Sensor Microwave Water Vapor Profiler (SSM/T-2)
Special Sensor Ultraviolet Limb Imager (SSULI)
Special Sensor Ultraviolet Spectrographic Imager (SSUSI)

STATUS

Launch Dates: 1970s to 2005
F-8 June 19, 1987
F-9 Feb 2, 1988
F-10 Dec. 1, 1990

F-I 1 Nov. 28, 1991
F-I 2-F20 Launched on need

Launch Vehicle: Atlas (F-8 to F-12)
Titan II (F-13 to F-20)

Number of Sensor Platforms: At least two satellites with a fully operational linescan system will be in orbit at all times. Mission sensor data from other satellites is collected when ground resources are available.

PLATFORM CHARACTERISTICS

Altitude:	Nominal 833 km
Type orbit/Inclination:	Circular, sun-synchronous, polar, 98.7"
Orbital Period:	101.8 minutes
On-Orbit Mass:	Payload-Dependent
Lifetime of Platform:	36 months mean mission duration
Period of Oberation:	until satellite failure
Power System:	solar array, 2 or 3 50 ampere hour batteries, dependent on spacecraft, power conditioning
End-of-Life Power:	425 watts (5D2), 760 watts (503 S15+)
Thermal Control System:	louvers, radiators, heaters, blankets
Stabilization Method:	3 axis stabilized, momentum wheels and magnetic torquer
Attitude Determination Accuracy:	0.01°, and angular disturbances of less than 0.03°/second

Planned Deployments of DMSP Sensors - S-1 5 (F-14) is shown as being launched before S-14 (F-15).

Instrument	F8	F9	F10	FII	F12	6	F13	F14	5̄17F1		F18	F19	F20
OLS	X	X	X	X	X	X	X	X	X	X	X	X	X
SSB/X- M,	2	x	x	x	x	x	X	X					
SSIES/2	x	x	x	x	x	x	X	X					
SSIES/3									x	x	x	x	x
SSJ/4	x	x	x	x	x	x	X	X					
SSJ/5									x	x	x	x	x
SSM					x	x	x	x	x	x	x	x	x
SSM/I	X		x	x	x	x	x	X					
SSMIS									x	x	x	x	x
SSM/T1	X	X	X	X	X	X	X	X					
SSM, T2				x	x		x	x					
ssuu									x	x	x	x	x
SSUSI									x	x	x	x	x
Launch	87	88	90	91									

DoD DATA SYSTEMS: The sensor data is recorded on four 1.7 Gigabit tape recorders and played back nominally once an orbit to the DoD Centrals through command read-out sites located at Fairchild AFB, WA; at AFSCN Remote tracking stations at New Boston, New Hampshire and at Thule AFB, Greenland. An AFSCN site at Hawaii is also used for playbacks. The recorded data is played back at 2.66 Mbits/second at 2252.5 GHz and 2267.5 GHz in an encrypted format. The data is multiplexed with voice data at the sites and relayed at 3.072 Mbits/second over domestic communication satellites to Site III at Air Force Global Weather Central, Offutt AFB, Nebraska and to Fleet Numerical, Meteorological, and Oceanographic Center, Monterey, California.

At Site III, the data stream is routed to three major processing systems: (1) the cloud depiction and forecast system (CDFS) - a UNISYS based mainframe system, (2) the Satellite Data Handling System (SDHS) - a VAX based distributed processing system, and (3) a data archive system which accumulates orbital data to be sent to the NGDC at Boulder, Colorado on high density cartridge tapes. The original environmental products are produced on the UNISYS systems and integrated into models. Most of the DMSP sensors have software processing packages which run on the UNISYS machines. Therefore, the raw data formats have historically been 36-bit oriented, reflecting the architecture of these computers. AFGWC has been moving towards distributed processing and has incorporated SSM/I processing into the Satellite Data Handling System ingest processing.

At Fleet Numerical, Meteorological, and Oceanographic Center, the Navy routes the SSM/I raw data to the Satellite Processing System Upgrade - a Concurrent Computer based system. After processing, the data is archived and sent to the National Snow and Ice Data center.

In coordination with NOAA, NASA, and DMSP, a DMSP data archive system was established at the National Geophysical Data Center. At this center, all the OMSP sensors will be archived on 8 mm cartridge tapes. The center utilizes a network of Sun computer systems (Sparc 10's and 690 MP's) to convert the original data archive cartridge tapes received from AFGWC, into earth located sensor data records for the scientific users. The DMSP data is placed into 7 data bases, which may be accessed remotely or requested on 8 mm Exabyte tapes.

Real time data is normally transmitted to tactical users at 2252.5 GHz, but can be transmitted at 2207.5 GHz and 2267.5 GHz. For F16 - F20 data will be transmitted at 2222.5 GHz and at UHF frequencies. The Real time data rate is 1.024 Mbits/second for high resolution data. Real time data smooth (RDS) is transmitted at 133kbits/second up through S-I 5 (66 kbits/second effective data rate) and at 177 kbits/second for S-16 and above (88 kbits/second effective data rate). Both real time channels contain the OLS imagery and mission sensors in encrypted format.

Table I DMSP Sensors and Processing Systems

Sensor System	COFS	SDHS	DDA	SPCU	Mark IV	Mark IVB	STT	AFSFC	SMQ11 TESS
OLS	X	X	X	X	X	X	X		X
SSM/I	X	X	X	X		X	X		X
SSMIS	P		P	P		P	P		P
SSM/T1	X		X			X	X		
SSM/T2	X		X			X	X		
SSB/X			X						
SSIES			X					X	
SSJ			X					X	
SSM			X					X	
SSUSI			P					P	
SSULI			P					P	

Notes: P = planned efforts, X = existing capability
COFS - Cloud Depiction and Forecasting System (AFGWC)
DDA - Digital Data Archive

SDHS - Satellite Data Handling System (AFGWC)
AFSFC - Space Forecast Center, Falcon AFB, CO
SPCU - Satellite Processing Center Upgrade (FNMOC)
Mark IV - Transportable Satellite Terminal (Air Force, Marines)
Mark IVB - Meteorological Satellite Processing Terminal (Air Force)
STT - Small Tactical Terminal (Air Force, Army)
SMQ11 - Ship board terminal system (Navy)
TESS - Tactical Environmental System (Navy)

Point of Contact:

Dr. H. Kroehl, NOAA/NGDC, 303-497-6121.

B. NOAA/NASA Data Systems:

SSM/I data products are being generated by the National Snow and Ice Data Center (NSIDC) and Marshall Space Flight Center (MSFC)--both of which are EOSDIS Distributed Active Archive Centers (DAACs). MSFC will produce and distribute the Pathfinder full-resolution (satellite swath) data sets, along with the selected algorithms for derived products. In addition, NSIOC has created and distributed gridded products (e.g., brightness temperature) resulting from the algorithms chosen by the SSM/I Science Working Group (SWG). Examples of the NSIOC products follow:

Daily, global Level 3 brightness temperatures (separated by ascending and descending orbits)

Gridded geophysical products (using the Level 3 brightness temperatures) from among several candidates

- Precipitation (oceans)
- Wind Speed (oceans)
- Water Vapor (oceans)
- Cloud liquid water (oceans)
- Sea Ice (oceans)
- Snow cover (land)
- Surface temperature (land)
- Vegetation cover (land)
- Surface type (land)

The above products will be provided at 5 day or calendar month time resolutions. The grid sizes for the brightness temperatures are 12.5 and 25 km corresponding to the different sampling and footprint sizes of the SSM/I.

The MSFC SSM/I Pathfinder project generates both antenna temperature and derived geophysical products. Daily antenna temperature data sets are generated and archived. Nine geophysical products have been identified:

- Precipitation
- Marine Wind speed
- Columnar water vapor
- Columnar liquid water
- Land surface type classification
- Land surface temperatures
- Vegetation index
- Sea Ice
- Snow cover extent

Point of Contact

H. Michael Goodman, Marshall Space Flight Center, Alabama 35806

Operational Linescan System

SENSOR CHARACTERISTICS

Sponsoring Agencies: DoD and USAF

Sensor Contractor: Westinghouse Electric Corporation, Baltimore, MD

Description: The primary sensor of the DMSP system, this sensor provides day and night cloud cover imagery from which cloud type, percent cloud cover, and cloud height are derived. The sensor provides radiometric data in the visible and thermal infrared. It consists of an oscillating six-inch telescope driven in a sinusoidal motion by a pulsed motor and counter-reacting coiled springs. The sinusoidal motion provides a relatively constant ground track velocity avoiding the sampling problems of a purely rotational system. The rotation of the instantaneous field of view on the rectangular detector and detector selection provides a nearly constant ground resolution, narrowing the angular field of view as a function of scan angle from nadir to the edge of scan. The visible channel is dynamically gain adjusted to provide uniform albedo information across the terminator regions, taking into account the bi-directional reflectance distribution function of an average scene, preventing the saturation of the visible channel.

The operational line system provides night time visible imagery with special precautions used to reduce glare on both the spacecraft with a glare obstruction bracket, and special sunshields on the OLS. This, along with dynamic gain control, allows the instrument to provide terminator coverage to support the military mission.

The scanner operates at 11.88 ± 1% lines per second with the rate varying slightly over an orbit. It has an active scan angle of ±55.25 degrees, with calibration done during the overscan periods. The sensor provides all the data handling for itself and the mission sensors.

Characteristics:

Spectral Band Centers and Widths:

visible - day	0.75 ± 0.35 pm
visible - night	0.65 ± 0.25 µm
infrared	11.5 ± 1.0 µm

Spatial Resolution - Each Band:

at nadir (0°)

visible - day	0.5 km (fine)	1.8 km (smooth)

visible - night	2.5 km (fine)	5.5 km (smooth)
infrared	0.5 km (fine)	1.8 km (smooth)
at edge (55')		
visible - day	0.9 km (fine)	4.3 'km (smooth)
visible - night	2.5 km (fine)	5.5 km (smooth)
infrared	1.8 km (fine)	4.3 km (smooth)

Swath Width: 3000 km

Spectral Response:

Measurement/Calculation Technique: Spectral response is measured for each optical component and theoretically convolved to get spectral response of the system. End to end spectral measurements made on some of the units show an increase in blue sensitivity over theoretical values.

Responsiveness of Sensor Channels: Infrared data is measured between 190° K to 310° K with a noise figure less than 2.2" K for fine data and 0.9" K for smooth data, measured at 210° K. The instrument is specified to have a temperature accuracy of less than 1.1° K RMS for constant radiance input. Most systems perform better than the specification requirements.

Visible data is measured between 2.2 x 10^{-2} W cm-2 sr-1 to 1 O-9 W $cm^{-2}sr^{-1}$. The visible day segment operates between 2.2 x 1 0^{-2} W cm-2 sr^{-1} to 5.5 x 10-5 W cm-2 sr^{-1}, while the night time photomultiplier operates between 5.5 x 10'5 W $cm^{-2}sr^{-1}$ to 1 O-9 W cm-2 sr^{-1}. The analog daytime radiometric accuracy is 7% at 1 x 10^{-2} W cm-2 sr^{-1}, while the night time accuracy is 60%.

Additional radiometric errors occur because of 6 bit and 8 bit quantization and deviations in the analog converters of about 1% in both the visible and infrared channels.

Calibration/Validation

Detailed Techniques for Data Calibration:

On-Board Methods: Warm load and cold target provided to measure detector gain, but no end-end calibration. Temperatures are compensated on board for variations in the primary mirror temperature. Gain is commanded to maintain temperature to 1 .1° K.

Visible channel dark current is available in telemetry. Gain is dynamically varied across the scene *to* provide the best image quality for interpretation. Gain corrections can be reversed with knowledge of scan angle and sun angles and the current coefficients

uploaded to the OLS memory. These currently are not stored with the archived data.
Ground Methods: Ground systems have thermal channel correction tables if necessary to correct the data.
Standards for Comparison: National Bureau of standards Blackbody targets are used to measure the OLS thermal channel in ground testing. Test results are available for all sensors.

Data Rate: 60 kbits/second smooth data (global coverage)
1,330 kbits/second fine data (visible and infrared)
660 kbits/second fine data (single channel only)
1,024 kbits/second real time data (one channel smooth, one channel fine, and mission sensor data)*

* Imagery data 633 kbits/second of the 1024 kbits/second.

Data Product:

Geophysical Measurements. The Operational Linescan System provides day and night cloud imagery, cloud heights, percent cloud cover, and cloud type. The processed cloud data at an eighth mesh resolution is sent to the US Air Force Environmental Technical Applications Center (USAFETAC) where statistical data sets on cloud cover are available.

The digital imagery is archived at the National Geophysical Data Center. Please contact Dr. H. Kroehl, NOAA/NGDC, 303-497-6121.

Special Sensor SSB/X Model 2 (SSB/X-2)

SENSOR CHARACTERISTICS

Sponsoring Agencies: DoD and USAF
Sensor Contractor: Sandia National Laboratory

Description: The SSB/X-2 is an energetic particle (proton/electron) and gamma ray monitoring instrument which supports the Air Force Technical Application Center (AFTAC) atmospheric/space NUDET monitoring mission. The instrument is a single box flight unit. This box houses an array of 2 gamma sensors and 3 particle sensors and associated electronics. Each of the five sensors in the array consist of a scintillator optically coupled to a photomultiplier tube (PMT). The geometry of the array is optimized for detecting the annihilation gamma emitted by a positron decay in the particle sensor. The signal from each PMT is processed by a multichannel pulse height analyzer. There is a separate adjustable High Voltage supply for each PMT.

The data acquisition and formatting logics are designed around an 80C85 microprocessor. Algorithms running on the microprocessor perform data collection, data compression, event determination and event data storage.

Each of the two gamma sensors consist of a 5 cm thick x 20 cm diameter monocrystal NaI scintillator coupled to a 2' PMT. The shape of the scintillator is that of a modified right circular cylinder. This shaping was necessary to fit the sensor into the instrument's volume and mass envelopes. The resulting volume is approximately 310 cm^3 per crystal.

The particle sensor portion of the array consists of a sectored 1.238" thick x 1.95" outside radius x 1.05' inside radius half ring-disk of scintillating plastic that has been divided into three sectors. Between adjacent sectors there is a 0.25' thick aluminum collimator to optically isolate adjacent sectors and define a sector Field of View which is 60° in the spacecraft's XY plane. The spacecraft's velocity vector is along the Y axis and the X axis is nadir pointing.

Characteristics: The data collected for the AFTAC mission consist of 7 spectral channels over the range 40 kev - 5 MEV collected from each of two gamma sensors and 4 spectral channels over the range 200 kev - 5 MEV collected from each of three particle sensors every 2 seconds. The instrument also has capabilities to detect and characterize positrons trapped in the geomagnetic field and cosmic gamma ray burst events. These data can be presented with the full spectral resolution of the system's 256 linear channels for each gamma sensor and 16 logarithmic channels for each particle sensor. The nominal time resolution of the gamma ray burst time history is 12.8 ms. Using a time to spill circuit, this resolution improves at the peak of large events. It is possible to correlate gamma ray burst events to within 10 ms of Standard Time.

Spatial Resolution: The array's in-track Field of View is 60° for each of 3 sectors for a total of 180°. The cross track Field of View is ±45°.

Spectral **Response:** Each gamma sensor has a 0.010 inch lead shield applied to all scintillator surfaces except for one of the cylinders two faces. This shield then defines a low energy aperture whose pointing axis is normal to this unshielded face. The signal response in this aperture at energies below the cutoff energy of the shield is a function of the angle of incidence and in general, follows the cosine law. The pointing axis of the two gamma sensors are mutually perpendicular to the spacecraft velocity vector and nadir axis and 180° from each other. This provides a good cross track source discrimination and some degree of angular resolution. For energies above the cutoff energy of the lead shield the gamma sensors become omni directional.

Calibration/Validation The gain and offsets of the gamma sensor are calibrated using the two energy lines of non-flight Na^{22} sources. In flight calibration relies on observation of the natural background (such as the annihilation peak) and the activation energies of the scintillator.

The particle sensor calibration is crude but consistent with the sensor's resolution and mission requirements. The response from a Bi^{207} source is used to set the system gain by monitoring the voltage input to the digitizer after allow for the measured electronic offset.

Data Rate: 180 bits per second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second or 1.024 Mbits/second channels, S Band).

Data Product: The Geophysical Measurements include: A measure of the gamma ray and charged particle flux and energy spectrum throughout the DMSP orbit, a coarse measurement of the pitch angle distribution of the particle fluxes, identification of positrons and a collection of gamma ray burst data with either high time resolution and high energy resolution (but not both for any given burst).

The digital raw data is archived at the National Geophysical Data Center. Please contact Or. H. Kroehl, NOAA/NGDC, 303-497-6121.

Special Sensor Ionospheric Plasma Drift/Scintillation Monitor (SSIES-2, SSIES3)

SENSOR CHARACTERISTICS

Soonsorina Agency(ies): DoD and USAF
Sensor Contractor: Univ. of Texas, Dallas; Lockheed Sanders
Description: A Langmuir probe, planar ion collector, scintillation meter, and plasma drift meter are used to derive the characteristics of the space plasma above the peak of the F region of the ionosphere.

The Ion Scintillation Meter is a planar electrostatic ion trap with a circular aperture, 7 cm in diameter. The purpose of the scintillation meter is to measure small scale variations in the local ion density. The aperture is covered by a grid which is held at the same potential as the sensor housing and the controlled section of the ground plane. Inside the instrument case there is an electron suppressor grid and a flat plate collector. The collector is connected to a linear electrometer capable of measuring d.c. currents and a.c. currents up to several kHz.

The ion Retarding Potential Analyzer is a planar electrostatic ion trap with a circular aperture, 4.0 cm in diameter. The aperture is surrounded by a voltage plane extending at least 14 cm in all directions from the aperture. The aperture is covered by a grid which is held at the same potential as the ground plane. The bias voltage is swept in a period of 4 seconds, with the collector current measuring densities from 50 to 5 x 10^5 cm^{-3}.

The ion drift meter is a passive planar electrostatic ion trap with square aperture of 2.8 cm on a side. This aperture is surrounded by a voltage plane extending 14 cm in all directions from the aperture. The aperture is covered by a grid which is held at the same potential as the voltage plane. The collector is split into four equal quadrants.

Characteristics:

Spectral Band Centers and Widths: Resolves H, He, and 0 ions
Spatial Resolution - Each Band: 30 km (4 second sweep)

Spectral Response:

Responsiveness of Sensor Channels: measures density ranges from 50 to 5×10^5 cm-3 with the capability of detecting relative variations of 10%; measurement of electron and ion temperatures in the range of 500° to 10,000° K, with an accuracy of ± 500° K.; measurement of ion drift velocity over the range - 3.5 km/sec to +3.5 km/sec, with an accuracy of ± 0.05 km/sec; Measurement of small scale variations (0.01% to 100%) in local ion density from DC to 1.5 kHz.

Calibration/Validation

Calibration sources and procedures: every 64 scans, a calibration scan is done to find the best bias potential to use on the ground plane and to set the optimum voltage sweep ranges. The grid voltages can be held at fixed or varying potentials.

Standards for Comparison: Radar measurements of electron densities and temperatures.

Data Rate: 720 bits/second up to 1080 bits/second depending on satellite. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second - 5D2, 88 kbits/second - 503, or 1.024 Mbits/second channels, UHF and S Band).

Data Product:

Geophysical Measurements - Each Sensor: Planar ion collector measures ambient ion temperature and density of ionospheric thermal electrons and ions, and the plasma drift meter measures plasma motion, The Langmuir probe provides electron thermal temperature.

Processed SSIES data is available from Dr. F. Rich, Phillips Laboratory, 617-377-9664.

The digital raw data is archived at the National Geophysical Data Center. Please contact Dr. H. Kroehl, NOAA/NGDC, 303-497-6121.

Special Sensor Precipitating Electron/Ion Spectrometer (SSJ/4, SSJ5)

SENSOR CHARACTERISTICS

Sponsoring Agencies: DoD and USAF
Sensor **Contractor**: Amptek Inc.
Description: The SSJ/4 and SSJ5 are the most recent charged particle spectrometers that analyze low-energy electrons and protons at the DMSP spacecraft altitude of 833 km. Their main use is to determine the location of the equatorward boundary of the auroral oval in daylight. The SSJ5 is an upgraded version of the SSJ/4 with major design changes. The SSJ/4 used channeltron detectors to count ions and electrons in the 50 ev to 30 kev range and took one energy spectrum per second. These energetic particles were collected in the zenith direction and gave no indication of the direction of arrival. With the SSJ5, the instrument will have a mode which allows the angular distribution to be measured by using two pairs of nested triquadrispherical plates and microchannel plates. In the angular mode, the new sensor will take one energy spectrum at six angles every six seconds. In the energy mode, it will continue the SSJ/4 data with a notable addition: with the increased angular spread, trapped particles will be counted. This will tend to shift the auroral boundaries slightly over the SSJ/4 data sets.

Characteristics:

Spectral Band Centers and Widths: 19 energy intervals for ions and electrons from 50 eV to 30 keV. Width of energy bin is about 20% of mid-value, i.e.. 30 kev ± 3 kev.

Spatial Resolution - .35 km sample, 7 km spectrum, auroral boundary measured to 0.1° latitude at spacecraft longitude.

Angular Resolution - 8° by 15° in angular mode, 8° by 90” in SSJ/4 emulation **mode.**

Spectral Response:

Measurement: counts all electrons and ions of specific energies **that** enter the channeltron or the microschannel plates.

Responsiveness of Sensor Channels:

SSJ5	ions	4.8×10^{-2} cm2 sr^{-1}
	electrons	2.0×10^{-2} cm2 sr^{-1}

Calibration/Validation

Calibration stability: F-6 and F-8 sensors were compared and F-6 provided similar results after 4 years on-orbit. The SSJS microchannel plate is expected to degrade with time, but the sensor is designed to allow the plate voltage to be increased.

Absolute accuracy of flux measurements are very dependent on final sensor geometry and may vary from sensor to sensor. The exact geometry of the sensor and energy response is calibrated at Phillips Laboratory and is available in test reports for use in the data reduction.

Data Rate: 360 bits/second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second - 5D2, 88 kbits/second - 503, or 1.024 Mbits/second channels, UHF and S Band).

Data Product:

Geophysical Measurements: Measures the flux and energy spectrum of electrons and ions that precipitate from the magnetosphere and cause ionization and visible aurora in the ionosphere at high latitudes.

Processed data is archived at Phillips Laboratory. Contact Dr. D. Hardy (617-377-3989). Archived raw data is available from National Geophysical Data Center, Dr. H. Kroehl, NOAA/NGDC, 303-497-6121.

Special Sensor Microwave Imager (SSM/I)

SENSOR CHARACTERISTICS

Sponsoring Agency(ies): DoD and USAF
Sensor **Contractor:** Hughes Aircraft Corporation, Los Angeles, CA

Description: The SSM/I imager was first placed on the F-8 satellite in 1987. Ail satellites through S-l 5 will fly a microwave imager, except for F-9. The sensor was designed and built by Hughes Aircraft, with the basic algorithms developed by Hughes Aircraft and modified by the SSM/I validation team headed by Nf?L.The SSM/I imager contains seven channels, two vertical and horizontal channels for each frequency, except for 22 GHz. The instrument takes readings in the following frequency regions: 85 GHz, 37 GHz, 22 GHz, and 19 GHz.

The sensor conically scans the earth at a rate of 31.9 scans/minute (1.88 seconds per scan). The sampling provides 128 scene stations per scan for the 85 GHz channels (half Nyquist frequency) and 64 scene stations per two scans for the other channels (also half Nyquist frequency for 37 GHz channel). For a parabolic antenna size of 60 x 66 cm, the ground resolution for the 85 GHz channel is approximately 15 kilometers, while the 37 GHz channel has a 33 kilometer resolution, and the 19 GHz channel a 55 kilometer resolution.

Each scan consists of a cold reading, a warm load reading, and the scene stations. The cold reading utilizes a view to deep space (3" Black Body), and the warm load temperature (variable over an orbit) is read by three precision thermistors. Each sensor has a different calibration curve for each of these thermistors.

The brightness temperatures are used directly to measure typhoon locations and regions of heavy precipitation and severe weather. The remotely sensed environmental parameters (sea surface wind, ice fields, precipitation, total water vapor) are extremely important to the military and civilian users. The seven sensors and the follow on sensors provide a long term continuity of information and make it very worthwhile for scientists to improve on the initial algorithms that are used at the weather centrals.

Characteristics:

Spectral Band Centers and Widths: see table
Spatial Resolution - Each Band: see table

Sampling: Only the 19 GHz channels are Nyquist sampled at 25 km.
Swath Width: 1290 km

Channel	Frequency (GHz)	Polarization	Bandpass (MHZ)	Resolution-CT (km)	Resolution AT (km)	NEDT (° K)
1	19.35	V	±250	55	55	0.73
2	19.35	H	±250	55	55	0.73
3	22.24	V	±250	55	55	0.73
4	37	V	±1000	33	33	0.55
5	37	H	±1000	33	33	0.55
6	85	V	±1500	15	15	1.00
7	85	H	±1500	15	15	1.00

CT = Cross Satellite Track
AT = Along Satellite Track

Spectral Response:

Measurement/Calculation Technique:
Responsiveness of Sensor Channels:

Calibration/Validation

Calibration sources and Procedures. A warm load and deep space 3° K reading are made each scan.
Detailed Techniques for Data Calibration:

On-Board Methods: None, raw counts are sent down.
Ground Methods: Ground software uses the warm and cold load readings to change counts into antenna temperatures, which are then corrected by antenna pattern correction into brightness temperatures.
Standards for Comparison: Each sensor is measured during ground testing at 10 separate temperatures (82° K to 360° K). The error curves are available for each sensor.

Data Rate: 3276 bits per second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second or 1.024 Mbits/second channels, S Band).

Data Product:

Geophysical Measurements:
Ice boundary (ICE, ice edge)
sea- ice morphology (IC, ice concentration)

wind speed (SWO, surface wind over ocean)
precipitation (RL, rain over land; RO, rain over ocean)
soil moisture (SM)
water vapor mass (WVO over ocean)
cloud water content (CWO over ocean)
snow depth (SND)
surface type (ST)
Radiative transmission (RT)
Brightness Temperatures.

The processed SSM/I data is available from the National Snow and Ice Data Center, Boulder, Co.

The earth located brightness temperatures are also archived at the National Geophysical Data Center. Please contact Dr. H. Kroehl, NOAA/NGDC, 303-497-6121.

13	19.35	V	500 [2]	47.0	77.1	0.7
14	22.235	V	500 [2]	47.0	77.1	0.7
15	37.0	H	2000 [2]	33.5	48.7	0.5
16	37.0	V	2000 [2]	33.5	48.7	0.5
17	91.655	V	1500 [1]	13.5	16.2	0.9
18	91.655	H	1500 [1]	13.5	16.2	0.9
19•	63.283248 ~0.2852721	H+V	3.0 [1]	75.2	75.0	1.9
20'	60.792668 ±0.357892	H+V	3.0 [1]	75.2	75.0	1.9
21'	60.792668 LO.357892 ±0.002	H+V	6.0 [1]	75.2	75.0	1.4
22'	60.792668 50.357892 ±0.006	H+V	12.0 [1]	75.2	75.0	1.0
23'	60.792668 to.357892 ±0.016	H+V	32.0 [1]	75.2	75.0	0.6
24'	60.792668 ±0.357892 +0.050	H+V	120 [1]	37.7	38.9	0.7

• channel center frequencies are shifted to take into account the Doppler shift caused by the spacecraft velocity in either the forward or backward direction.

[1]= IF Bandwidth

[2]= RF Bandwidth

CT = Cross Satellite Track

AT = Along Satellite Track

Spectral Response:

Responsiveness of Sensor Channels: Each channel has an absolute brightness accuracy of less than one degree K with a Noise Equivalent Difference Temperature as indicated in the table.

Calibration/Validation

Calibration sources and Procedures- Every channel of the SSMIS is calibrated once a scan with a cold view of deep space and a warm load reading. Calibration takes into account warm load errors, linearity corrections, dynamic range adjust, and gain variations with temperature of the sensor.

Calibration stability: All channels are total power radiometers and will have a stability of several seconds so that the warm and cold calibration points provide adequate calibration.

Detailed Techniques for Data Calibration:

On-Board Methods: The on board software scales the data to fit within a 12 bit range using the warm and cold load readings. Warm load thermistor readings are contained in the data stream. The temperature of the warm load is controlled over the orbit. Every other beam position has a separate integrator so that calibration is performed separately on the even and odd sets.

Ground Methods: Each channel will require secondary correction on the ground using data derived in ground testing for warm load calibrations.

Standards for Comparison: Testing at the sensor level uses liquid nitrogen. Linearity measured at six target temperatures from 183 to 330° K. Accuracy of less than 1° K will be measured in laboratory.

Data Rate: 14,220 bits/second; 26,000 bits/sensor revolution asynchronous to the Operational Linescan System. Data is provided to both centrals (2.66 Mbits/second) and tactical locations (88 kbits/second or 1.024 Mbits/second channels, UHF and S Band).

Data Product:

Geophysical Measurements - Each Sensor: Ice boundary, rain rate, relative humidity, water vapor mass, sea ice type (ice age), temperature profiles to 60 km, water vapor profiles to 300 mb, wind speed over ocean, soil moisture, cloud water content, snow water content, surface type, surface temperatures, Radiative transmission (RT), brightness temperatures.

The sensor is not currently flying, but should be on orbit by 1999.

Spectral Response:
Measurement/Calculation Technique
Responsiveness of Sensor Channels:

Calibration/Validation
Calibration sources and Procedures- Each Band
Calibration stability:
Detailed Techniques for Data Calibration:
On-Board Methods: Blackbody warm load and 3 degree view to space are provided each scan.
Ground Methods:
Standards for Comparison:
Methods of Calibration Transfer

Data Rate: 144 bits per second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second or 1.024 Mbits/second channels, S Band)

Data Product:
Geophysical Measurements - Each Sensor: Temperature profiles

Special Sensor Microwave Water Vapor Profiler (SSM/T-2)

SENSORS CHARACTERISTICS

Sponsoring Agency(s): DoD and USAF
Sensor Contractor: Gencorp - Aerojet Electronics Systems Division, Azusa,CA

Description: The SSM/T-2 is an advanced five channel passive microwave radiometer used to provide water vapor measurements. The instrument is a total power radiometer, using harmonic doubling of a basic 91 GHz oscillator to provide a mixer frequency at 183 GHz where an absorption line of water vapor is present. A cross-track scanner, It scans ± 40.5" about nadir perpendicular to the spacecraft velocity vector, taking readings every 3° in a step scan fashion. The basic period of the sensor is 8 seconds, with part of the scan used to obtain cold load readings (4) and warm load readings (4). The sensor provides automatic gain control to keep the observed brightness temperatures in a 12 bit range, with each channel's gain independently controlled. The sensor is synchronized with the SSM/T1 so that every fourth scan of the SSM/T2 begins at the same time as an SSM/T1 scan.

Characteristics:

Spectral Band Centers and Widths: See Table
Spatial Resolution - See Table:
Swath Width: 1400 km

Channel	Frequency (GHz)	Polarization*	Bandpass (MHZ)	Resolution nadir(km)	Resolution edge (km)	NEDT (° K)
1	183.310 ±3	H	1000	50	75	0.6
2	183.310 ±1	H	500	50	75	0.8
3	183.310 ±7	H	1500	50	75	0.6
4	91.655	H	1500	100	150	0.6
5	150.0	H	1500	60	90	0.6

* sensor is horizontally polarized at nadir parallel to spacecraft's along track axis. At other scan angles, a combination of Horizontal and vertical polarization is observed:

Special Sensor Magnetometer (SSM)

SENSORS CHARACTERISTICS

Sponsoring Agencies: DoD and USAF, Goddard Spaceflight Center

Description: The SSM is a triaxial fluxgate magnetometer with a resolution of 2 nano-Tesla in each axis. It is used to measure disturbances in the ionosphere and near-earth space environment which affect communication and surveillance systems. These disturbances cause variations in the local magnetic fields on the order of 200 nano-Tesla. They can reach values of 500- 1000 nT when crossing the Birkeland current systems. Typical variations are in the range of 200-500 nT under 'quiet' conditions. For S-1 1 to S-14, it will be hard mounted to the spacecraft. For S-l 5 to S-20,' it will be placed on a 5 meter boom to reduce the spacecraft interference. The magnetometer uses a ring core geometry, with the thermal expansion coefficients of the core, windings, and support structure carefully matched to minimize changes in the geometry in flight.

Characteristics:

Spatial Resolution - .08 seconds (corresponds to .5 km at nominal spacecraft velocities)

Instrument Response:

Measurement/Calculation Technique

Responsiveness of Magnetometer: Measures the magnetic field with a dynamic range of ±65,536 nano-Tesla. The instrument has a resolution of 2 nanb-Tesla.

Calibration/Validation

Calibration sources and Procedures- The instrument is calibrated in a controlled magnetic field through the full range of the instrument and is performed at 3 temperatures. The absolute magnetic field is measured to ± 20 nano-Tesla.

Detailed Techniques for Data Calibration:

On-Board Methods: Once a second, a full reading of the field is given. with deita values given for the next eleven samples. Overflow is possible. A calibration

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Instrument Response:

Measurement/Calculation Technique

Responsiveness of Magnetometer: Measures the magnetic field with a dynamic range of ±65,536 nano-Tesla. The instrument has a resolution of 2 nanb-Tesla.

Calibration/Validation

Calibration sources and Procedures- The instrument is calibrated in a controlled magnetic field through the full range of the instrument and is performed at 3 temperatures. The absolute magnetic field is measured to ± 20 nano-Tesla.

Detailed Techniques for Data Calibration:

On-Board Methods: Once a second, a full reading of the field is given. with delta values given for the next eleven samples. Overflow is possible. A calibration mode is available to increment the field by known amounts in the three axes.

Ground Methods: Especially on the body mounted sensors, interference effects of the spacecraft (for example heaters and other high current devices) must be removed from the data. Interference from other moving devices (SSM/I, SSM/IS) must be removed from the data.

Standards for Comparison: Calibration constants are measured for each instrument at the Laboratory for Extraterrestrial Physics and the Magnetic Test Facility of the Goddard Space Flight Center and provided in the ground processing.

Data Rate: 252 bits/second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (66 kbits/second - 5D2, 88 kbits/second or 1.024 Mbits/second channels, UHF and S Band).

Data Product:

Geophysical Measurements

Magnetic anomalies and mapping of the earth's magnetic field.

Field aligned currents measured as a time/spatial derivative of the magnetic field changes.

Special Sensor Ultraviolet Spectrographic Imager (SSUSI)

SENSOR CHARACTERISTICS

Sponsoring Agencies: DoD and USAF, Applied Physics Laboratory, John Hopkins University

Description: The SSUSI sensor measures the ultraviolet airglow at five wavelength intervals between 115 nm and 180 nm. The data is used in conjunction with other sensors to infer electron density profiles, to locate the boundary of the auroral oval, and to gauge the auroral activity.

Characteristics: Ultraviolet Spectrograph:

Spectral Band Centers and Widths: In the *imaging* mode, the sensor supports five separate UV channels that can be changed on-orbit. The sensor has 160 spectral bins from which 5 bins or sum of bins can be selected. The expected channels are:

channel	wavelength (nm)	resolution (km)	Minimum Intensities (Rayleighs)	Maximum Intensities (Rayleighs)	Source
1	121.6	10	2,000	30,000	geocoronal Lyman-a
2	130.4	10	1,000	20,000	atomic
3	135.6	10	50	4,000	oxygen
4	140-150	10	20	3,000	Lyman - Birge-Hopfield
5	165-180	10	160	2,000	bands of molecular nitrogen

Spatial Resolution: In the imaging mode, at nadir (normal resolution), the Basic resolution is 10 km x 10 km, with a backup configuration of a wide-slit provide a 24 km x 24 km. In the imaging mode, 16 spatial pixels are scanned every 22 seconds.

For environmental products, pixels are averaged:

Day side	100 km x 200 km
Night Side	100 km x 200 km
Auroral Zone	25 km x 50 km

Swath Width: Scan to 500 km tangent altitude above the horizon on anti-sunward side. A reduced scan on sunward side is used in the presence of the Glare Obstructor Bracket.

In the spectrograph mode of operation, the instrument is set to a fixed viewing angle. For sensor characterization, an entire spectrum is downlinked and either spectrum line positions are mapped to bins or a calibration is determined based upon observations of known stellar sources. The along track dimension of the detector array consists of six spatial pixels. Spectrum data from 160 bins are produced every 3 seconds. Three slit widths are available to improve sensitivity or spectral resolution, which ever is needed.

Photometer characteristics:

The instrument has three photometers for use in night time measurements. Each photometer has a 2 degree full angle cone. The center wavelengths and characteristics are given in the table. Channel 3 is used to correct for the background continuum observed in channel 2.

Photometer	Wavelength (nm)	Bandpass (nm	Resolution (km)	sensitivity (cnts/sec/R)
1	427.8	3.0	25	5
2	630	0.3	25	30
3	629.4	0.3	25	30

R - Rayleigh

Spectral Response:

Measurement/Calculation Technique:

Responsiveness of Sensor Channels:

at 121.6 nm, 0.015 counts/sec/Rayleigh (reduced for Lyman *a)*

at 130.4 nm, 0.116 counts/sec/Rayleigh

at 135.6 nm, 0.157 counts/sec/Rayleigh

at 140-150 nm, 0.128 counts/sec/Rayleigh

at 165-180 nm, 0.015 counts/sec/Rayleigh

Calibration/Validation

Calibration sources and Procedures- Each Band The current plan is to use UV stars as calibration sources when they are observed in the limb scans. They will also be used in the spectrograph mode.

Data Rate: 3816 bits/second (all modes). Data is provided to both strategic (2.66 Mbits/second) and tactical locations (88 kbits/second or 1.024 Mbits/second channels, UHF and S Band).

On-Board Methods: Periodic observation of about 30 bright ultraviolet stars. Calibration of stars traced to previous spaceflights.
Ground Methods: Comparison with ionosondes and ISR overflights.
Standards for Comparison: Sensor is calibrated at NRL's Vacuum Calibration facility, measuring absolute sensitivity, linearity, wavelength passbands, and field of views.
Methods of Calibration Transfer: Sensor provides the ability to rotate down to -20 degrees for cross checking with the SSUSI sensor.

<u>Data Rate</u>: 2520 bits/second. Data is provided to both strategic (2.66 Mbits/second) and tactical locations (88 kbits/second or 1.024 Mbits/second channels, UHF and S Band).

<u>Data Product</u>:

Geophysical Measurements: Instrument initial measures the air glow. It will provide day electron density profiles through reduction of the 0+ 834 Å line, and at night by the OI 97 1 and 1356 Å line. Neutral densities are derived in the day time from the OI 1356Å line and the LBH bands of N_2. At night, the OI lines at 1356 and 1304 Å will be used.

Data Product:

Geophysical Measurements: Dayside O/N_2 ratio, night time electron densities (F-region); auroral boundaries (day and night); and energy deposition in the auroral region (day and night).